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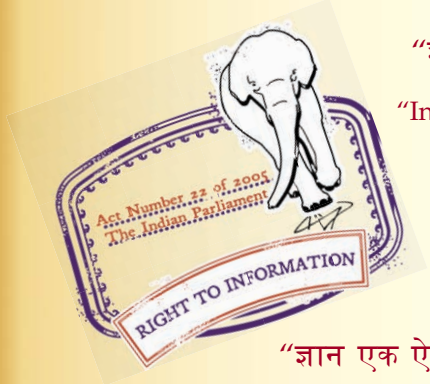

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"Knowledge is such a treasure which cannot be stolen"

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IS : 4853 - 1982
(Reaffirmed 2003)

Indian Standard

RECOMMENDED PRACTICE FOR RADIOGRAPHIC INSPECTION OF FUSION WELDED BUTT JOINTS IN STEEL PIPES

(First Revision)

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MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 4 *July* 1982

Indian Standard

RECOMMENDED PRACTICE FOR RADIOGRAPHIC INSPECTION OF FUSION WELDED BUTT JOINTS IN STEEL PIPES

(First Revision)

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Indian Standard

RECOMMENDED PRACTICE FOR RADIOGRAPHIC INSPECTION OF FUSION WELDED BUTT JOINTS IN STEEL PIPES

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 22 February 1982, after the draft finalized by the Non-Destructive Testing Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 This standard was first published in 1968. This has been now revised to bring it in line with the latest developments and current practice in this field, and also to align it with the international standards. This has been prepared on the basis of Document No. ISO/TC 44/N 644 E 'Recommended practice for radiographic inspection of fusion welded in circumferential joints in steel pipes up to 50 mm wall thickness'.

0.3 These recommendations are applicable to complete radiographic inspection of the welded pipe joints. They may also be used where only small sections, namely, spot checks and radiography of repaired sections are to be examined.

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1. SCOPE

1.1 This standard covers the recommended practice for radiographic inspection of fusion welded butt joints in steel pipes up to 50 mm wall thickness.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions given in IS : 2478-1963* shall apply.

*Glossary of terms relating to industrial radiology.

3. CLASSIFICATION OF RADIOGRAPHIC TECHNIQUES

3.1 The radiographic techniques are divided into the following two classes:

a) *Class A* — A general technique, adequate for most applications; and

b) *Class B* — A more sensitive technique intended for use where the usual method may give unsatisfactory results or is unlikely to reveal the anomalies sought. It generally requires longer exposure time.

3.2 In addition to having an adequate flaw sensitivity, some applications of radiography require the radiographs to cover a range of specimen thicknesses. Several modifications of either Class A or B shall produce an increase in thickness latitude.

3.3 The technique, required for a particular application should be agreed in advance between the purchaser and the supplier, taking account of the flaw sensitivity required, the thickness latitude necessary, the equipment available, cost, accessibility, etc.

4. GENERAL

4.1 Protection — The exposure of any part of the human body to X-rays or gamma rays may be highly injurious to health. It is, therefore, essential that whenever radiation sources are used, adequate precautions should be taken to protect the radiographer and any other person in the vicinity.

4.1.1 To ensure precaution against the exposure of personnel engaged in the use of industrial radiation sources, the safety requirements given in IS : 2598-1968* shall be followed.

4.2 Surface Preparation — In order to obtain the best flaw sensitivity, it is always advisable to remove surface defects before taking radiographs.

In general, surface preparation may not be necessary for radiography, but where surface irregularities might cause difficulty in detecting internal defects, the surface should be ground smooth.

4.3 Location of the Weld in the Radiograph — Markers, usually in the form of lead arrows or other symbols, should be placed alongside the weld on both sides of it, so that the position of the weld can be identified on the radiograph. This may not be necessary if the reinforcement is retained.

*Specification for radiographic image quality indicators (*first revision*).

4.4 Identification of Radiographs — Lead letters or symbols should be affixed to each section of the weld being radiographed. The images of these letters should appear in the radiograph to ensure unequivocal identification of the section.

4.5 Marking — In general, permanent markings on the work piece will provide reference points for the accurate re-location of the position of each radiograph. Where the nature of the material and its service conditions render stamping impossible, other suitable means for re-locating the radiographic zone must be sought. This may be done by paint marks, or by accurate sketches.

4.6 Overlap of Films — In radiographing a continuous length of weld, the separate radiographs should overlap sufficiently to ensure that no portion of this length remains unexamined.

4.7 Image Quality Indicators (IQI)

4.7.1 An IQI in steel should be of a type specified in IS : 3657-1978* and as agreed between the contracting parties. It should be placed at one or both ends of every section radiographed.

4.7.2 It should be placed on the surface facing the course of radiation, and in such a manner that the thinnest part or smallest diameter of the indicator is placed on the side furthest from the film where the thickness crossed by the ray is thickest and depending upon its type, adjacent to or accross the weld. Only where this surface is inaccessible should the IQI be placed on the film side. If this has to be done, a lead letter 'F' shall be placed alongside the IQI to have permanent record on the radiograph and to assess sensitivity obtained.

5. RECOMMENDED TECHNIQUES FOR MAKING RADIOGRAPHS

5.1 Setting Up of the Films and of the Source of Radiation — Depending on the size and accessibility of the joints any one of the following arrangements for relative position of film and source shall be selected:

a) *Film Inside, Source of Radiation Outside* (*Fig. 1*) —The source of radiation should be placed at a distance from the weld (*see* **5.5**) the axis of the cone of radiation being normal to the surface under examination at its centre. The cassette should be placed on the corresponding area inside the pipe, in close contact with the weld.

*Safety code for industrial radiographic practice.

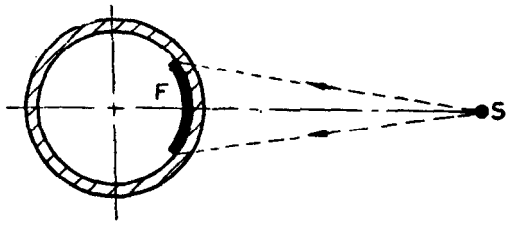


FIG. 1 FILM INSIDE; SOURCE OF RADIATION OUTSIDE

b) *Film Outside, Source of Radiation Inside* (*Fig. 2 and 3*) — The source of radiation should be set up inside the pipe, in the centre of the circumference if possible, though otherwise it may be placed eccentrically in the plane of the weld, the axis of the cone of radiation being normal to the surface under examination at its centre.

The cassette should be placed on the corresponding area outside the pipe in close contact with the weld.

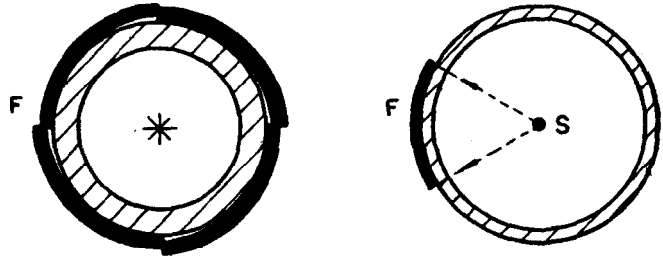


FIG. 2 FILM OUTSIDE; SOURCE OF RADIATION INSIDE; SOURCE CENTRAL

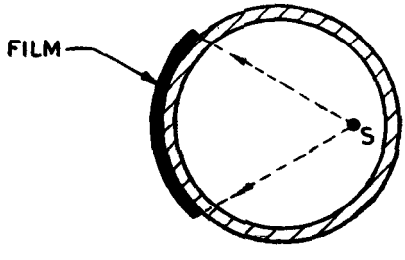


FIG. 3 FILM OUTSIDE; SOURCE OF RADIATION INSIDE; SOURCE OFF-CENTRE

c) *Film and Source of Radiation Outside — Double Wall, Double Image* (*Fig. 4*) — The source of radiation should be placed at a distance as defined below (*see* **5.5**) in a position so that the axis or the cone of radiation is inclined to the axis of the tube, and passes through the centre of the circumference containing the weld. The cassette containing the film which should be of sufficient length to contain the two images of the weld, should be placed against the tube wall furthest from the source, and disposed in such a manner that the axis of the X-ray beam passes through the centre.

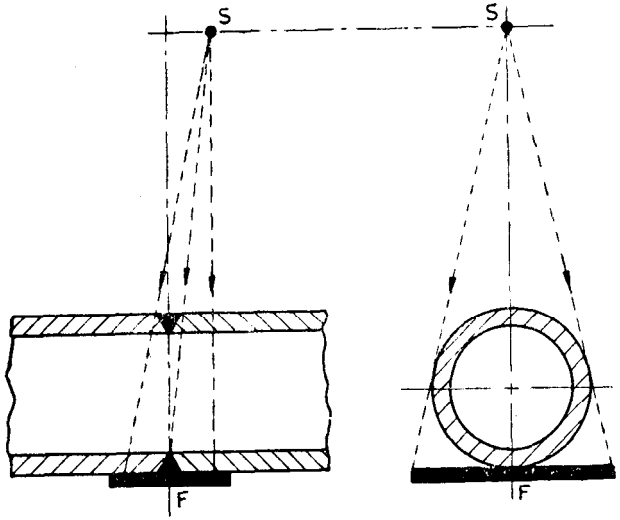
In this condition a minimum of two exposures shall be taken at 90° to each other (Fig. 4A). Alternatively the radiation beam axis can be kept perpendicular to the tube axis as shown in Fig. 4B thereby superimposing the weld images. If this method is applied, a minimum of three exposures shall be taken.

d) *Film and Source of Radiation Outside — Double Wall, Single Image* (*Fig. 5*) — The source of radiation should be placed so as to achieve the minimum focus-to-film distance compatible with the source size and wall thickness to be examined. If possible the source should be in contact with the pipe, with the radiation passing through the parent metal adjacent to the weld but this may not be possible with small diameter pipes. The film should be placed on the side of the pipe further from the source of radiation, in close contact with the weld, the axis of the cone of radiation passing through the centre of the portion of weld under examination.

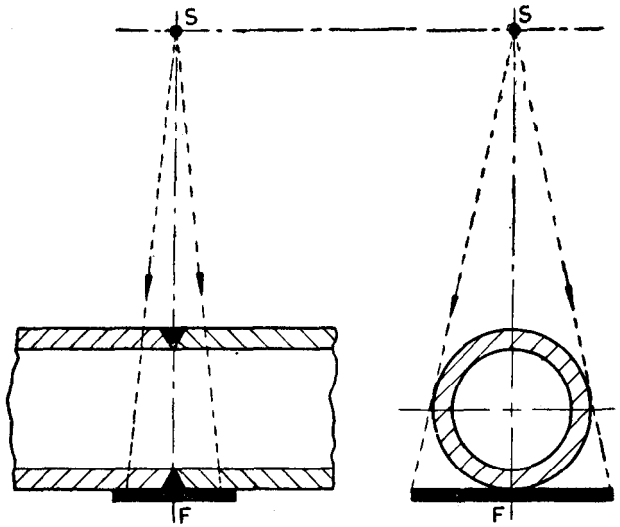
5.1.1 The following suggestions are given as general guidance in the selection of the appropriate technique:

a) *Film Inside, Source of Radiation Outside* — This technique should be used for large cylindrical bodies, whereas the limitation (*see* **5.6**) of maximum area to be examined permit the use of long films whilst keeping the focus-to-film distance within reasonable limits.

b) *Film Outside, Source of Radiation Inside* — When applicable, this technique should be considered as the most convenient, because the source being situated at or near the centre, there is no restriction as regards the area examined. For this technique, hollow anode X-ray tubes or gamma-ray sources may be used as radiation sources. This technique is particularly recommended for pipes with heavy wall thickness and small diameter, provided the minimum source-to-film distance is satisfactory as per the conventional formula.



4A Inclined Shot



4B Perpendicular Shot

FIG. 4 FILM AND SOURCE OUTSIDE; DOUBLE IMAGE

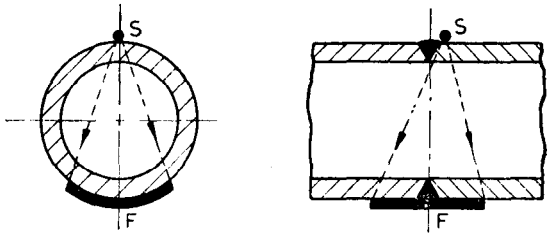


FIG. 5 FILM AND SOURCE OF RADIATION OUTSIDE; DOUBLE WALL, SINGLE IMAGE

c) *Film and Source of Radiation Outside — Double Wall, Double Image* — This technique should be used for pipes having diameters not exceeding approximately 100 mm, the necessary focus-to-film distance being too large with larger diameters; it should be noted, however, that the increase of wall thickness restricts the length of weld which can be properly radiographed.

d) *Film and Source of Radiation Outside — Double Wall, Single Image* — This technique will give the best results for pipes not accessible from inside, with diameters larger than approximately 100 mm. It can be used for pipes with diameters up to about 900 mm, beyond which the source-to-film distance becomes too great.

5.1.2 *General Comments* — Whenever possible, in particular when a large part of the X-ray beam is used for covering the area to be irradiated, operators are recommended to set up the X-ray tube in such a way that the axis of the electron beam (inside the tube) is parallel to the pipe to be radiographed. This ensures the best image definition, even at the extremities of the film, and a more uniform distribution of the intensity of the radiation.

5.2 Choice of Film and Intensifying Screens

5.2.1 *Film Types* — The types of industrial X-rays, films suitable for industrial radiography are given in Table 1.

5.2.1.1 For Class A techniques, GI, GII and GIII films, and for Class B technique GI and GII should be used. GIV films are only recommended to be used with fluorescent or fluoro-metallic screens.

5.2.2 *Intensifying Screens* — Screens of metal foil of thicknesses given in Table 2 of IS : 2595-1978* should be used. These screens shall be clean,

*Code of practice for radiographic testing (*first revision*).

smooth and free from mechanical defects which might affect the interpretation. They shall be held in close contact with the film emulsion.

TABLE 1 CLASSIFICATION OF X-RAY AND GAMMA-RAY FILMS

(*Clause* 5.2.1)

Film Classes	Graininess	Speed
(1)	(2)	(3)
GI	Very fine grained film	Very slow
GII	Fine grained film	Slow
GIII	Film with medium grain size	Medium speed
GIV	Film with larger grain size	High speed

5.2.2.1 *Fluorescent/fluoro-metallic screens* — In general for a given source of radiation, fluorescent/fluoro-metallic materials should be used only when the exposure necessary without them would be prohibitively long. In any event, if such fluorescent/fluoro-metallic screens should be used, they should be proven capable of achieving the required quality level. Good screen-to-film contact is essential for the successful use of fluorescent/fluoro-metallic screens.

5.2.2.2 In the double film technique intermediate screens should be used.

5.2.3 *Cassettes and Film Holders* — Films and screens should be contained in cassettes. The cassettes for holding film may be either rigid or flexible depending on the specimen and the circumstances under which the radiograph is taken. When screens are used in combination with the film a good uniform contact between screens and film is important. In such cases, use of rigid, spring back cassettes is recommended. Cassettes may be pressed or clamped against the material to be radiographed. The weight of the material or the flexing of the cassettes, when bent to fit inside some structure, may be used to ensure contact.

5.3 Alignment of Beam — The beam of radiation should be directed to the middle of the section under examination and should be normal to the plate surface at that point, except when especially seeking certain defects which are known to be best revealed by a different alignment of the beam, such as, defects at a fusion face, and the exposure should then be made with the beam directed along the fusion face.

5.3.1 This general rule should be applied with the following to exceptions:

a) When using the double wall, double image technique, the inclination of the beam should be such as to avoid a superimposition of the two images. This inclination will depend on the diameter of the pipe, its wall thickness and on the width of the welded seams.

b) For the technique in which the X-ray beam passes through the two walls, but only give a single image, the displacement of the source from the plane of the weld should be just sufficient to avoid superimposition of the images of the two portions of the weld and the inclination of the axis of the X-ray beam should be such that the axis passes through the middle of the portion of weld under examination.

5.3.2 In order to eliminate possible interference when a backing ring has been used and to provide the best possibility of fine cracks in the first run being revealed, it is suggested that, where the diameter of the pipe permits, the beam should be normal to the weld, non inclined, and centered in the plane of the weld. Figures 6 to 10 show the recommended alignments for various types of weld joint.

5.4 Interception of Unwanted and Scattered Radiations — The film should be shielded from all back scattered radiation by an adequate thickness of lead, say 1·5 mm or more, placed behind the film screen combination. On account of the back radiation originated by the lead itself it is suggested that a tin sheet about 1 mm thick, or preferably a tin and a copper sheet, each 1 mm thick, should be inserted between the lead plate and the film-screen combination.

Moreover, in order to reduce the effect of internally scattered radiation adequate masking should be provided so as to limit the area irradiated to the section under examination.

5.4.1 When using the double wall techniques [*see* 5.1(c) and 5.1 (d)], in particular on small diameter pipes, adequate masking should be provided to ensure that only direct radiation strikes the film.

5.5 Focus (Source)-to-Film Distance — The distance between the film and the adjacent weld surface should be as small as possible.

The minimum focus (source)-to-film distance (f_{Min}) depends on the effective dimensions (d of the focal spot or source and on the distance (b) between the film and the surface of the specimen facing the X-ray tube or radioactive source.

The resulting geometric unsharpness u can be calculated from the formula:

$$u = \frac{b\ d}{f_{min} - b}$$

The value of u should not exceed 0·4 mm for Class A technique and 0·2 mm for Class B technique.

5.5.1 When using single wall techniques given in 5.1(a) and 5.1(b), the minimum source-film distance should be calculated directly from the conventional formula.

5.5.2 When using double wall technique 5.1(c), it is necessary to introduce in the formula for b the external diameter of the pipe instead of its wall thickness.

In the following table the approximate minimum source-film distances are given as a multiple of the external diameter for Class A, Class B and for different focal spot sizes.

	Class A $u = 0{\cdot}4$ mm					Class B $u = 0{\cdot}2$ mm				
Focal spot in mm	2	3	4	5	6	2	3	4	5	6
f_{min} (expressed in units of pipe diameters)	5	7·5	10	12·5	15	10	15	20	25	30

5.5.3 When using double wall technique 5.1(d), the minimum source-film distance should be calculated by introducing into the formula, for b only, the actual wall thickness of the section of circumference under examination. It should be noted that, with this technique when the outside diameter of the pipe plus the actual distance between source and X-ray outlet port is not less than the minimum source-film distance required, there are no objections to putting the X-ray equipment or the radioactive source in close contact with the pipe.

5.6 Size of the Area Examined — The maximum area to be considered for each exposure shall be determined by the difference between the thickness of the material penetrated in the centre and that at the extremities measured in the direction of the beam at those points. The differences in density resulting from this variation of thickness and recorded on the film should not exceed the admissible limits specified in **5.7.**

It should be noted that this limitation not only ensures the best utilisation of the film characteristics, but also reduces the distortion of the image at each extremity of the film.

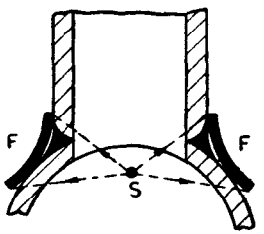


FIG. 6 FILM OUTSIDE; SOURCE INSIDE AND CENTRAL

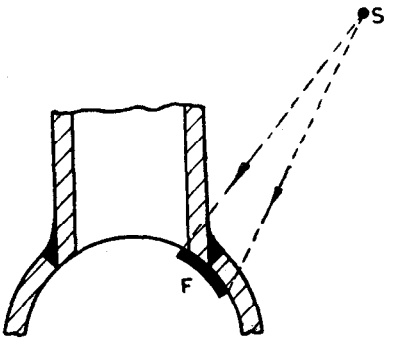


FIG. 7 FILM INSIDE, SOURCE OUTSIDE, SINGLE WALL PENETRATION

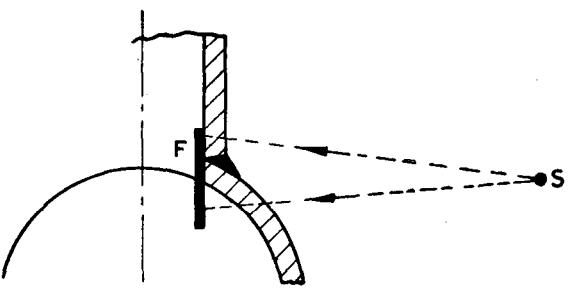


FIG. 8 FILM INSIDE; SOURCE OUTSIDE, SINGLE WALL PENETRATION

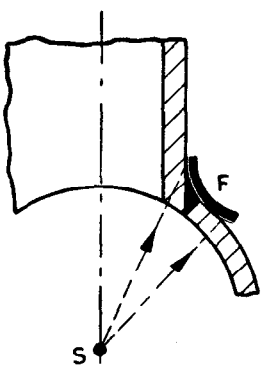


FIG. 9 SOURCE INSIDE AND CENTRAL; FILM OUTSIDE

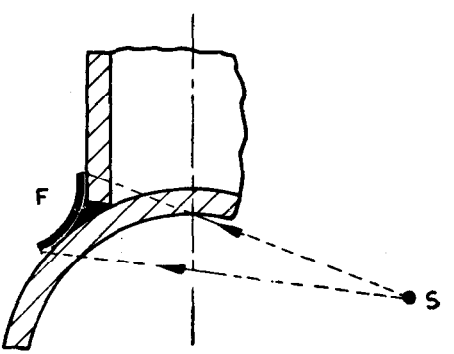


FIG. 10 SOURCE INSIDE, OFF CENTRE; FILM OUTSIDE

5.7 Radiograph Density — Exposure conditions should be such that the density of the radiograph of the sound weld metal in the area under examination, including fog density, lies within the range:

Class A	*Class B*
1·7 to 3·0 for non-screen type films	
1·3 to 2·3 for screen-type films for the exceptional case where this type of film is used	2·0 to 3·0

5.7.1 Higher densities may be used with advantage where the viewing light is sufficiently bright to permit adequate interpretation. Precautions should be taken to avoid glare.

5.7.2 In order to avoid unduly high fog densities arising from film ageing, development, or temperature, the fog density should be checked from time to time on a non-exposed sample taken from the films used, and handled and processed under the same conditions as the actual radiographs. The maximum chemical fog densities should not exceed 0·2.

5.8 Tube Voltage of X-ray Source — In order to increase the contrast, the tube voltage must be as low as practicable. As a basis, the kilovoltage should be chosen so as to give an appropriate density with an exposure of not less than 8 mA minute for Class A, and not less than 15 mA minute for Class B, for a focus-film distance of about 760 mm; the time should in no case be less than 1 min.

5.9 Radioactive Sources — Radioactive sources give the best results in the following thickness ranges:

Source	*Steel Thickness* mm
Ir — 192	10-60
Ca — 137	25-100
Co — 60	40-140

5.10 Processing — Films should be processed in accordance with the recommendations of the film manufacturers. Particular attention should be paid to temperature and developing time. The radiographs should be free from imperfection due to processing or other causes, which would interfere with interpretation.

5.11 Viewing — The radiographs should be examined in a darkened room on an illuminated diffusing screen and the illuminated area should be masked to the minimum required for viewing the radiographic image. The brightness of the viewing screen should preferably be adjustable so as to allow satisfactory reading of the radiographs.

5.12 Recording Technical Data — For each radiograph, or set of radiograph information should be available on the radiographic technique used, and on any other special circumstances which would allow a better understanding of the results.

In particular, the following should be stated:

a) type of X-ray equipment, tube voltage and current;

b) characteristics of the radioactive source (nature, size, nuclear activity, etc);

c) time of exposure, type of film and screen, focus source-film distance; and

d) system of marking used.

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Central Laboratory :	
Plot No. 20/9, Site IV, Sahibabad Industrial Area, Sahibabad 201010	8-77 00 32
Regional Offices:	
Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002	323 76 17
*Eastern : 1/14 CIT Scheme VII M, V.I.P. Road, Maniktola, CALCUTTA 700054	337 86 62
Northern : SCO 335-336, Sector 34-A, CHANDIGARH 160022	60 38 43
Southern : C.I.T. Campus, IV Cross Road, MADRAS 600113	235 23 15
†Western : Manakalaya, E9, Behind Marol Telephone Exchange, Andheri (East), MUMBAI 400093	832 92 95
Branch Offices::	
'Pushpak', Nurmohamed Shaikh Marg, Khanpur, AHMEDABAD 380001	550 13 48
‡Peenya Industrial Area, 1st Stage, Bangalore-Tumkur Road, BANGALORE 560058	839 49 55
Gangotri Complex, 5th Floor, Bhadbhada Road, T.T. Nagar, BHOPAL 462003	55 40 21
Plot No. 62-63, Unit VI, Ganga Nagar, BHUBANESHWAR 751001	40 36 27
Kalaikathir Buildings, 670 Avinashi Road, COIMBATORE 641037	21 01 41
Plot No. 43, Sector 16 A, Mathura Road, FARIDABAD 121001	8-28 88 01
Savitri Complex, 116 G.T. Road, GHAZIABAD 201001	8-71 19 96
53/5 Ward No.29, R.G. Barua Road, 5th By-lane, GUWAHATI 781003	54 11 37
5-8-56C, L.N. Gupta Marg, Nampally Station Road, HYDERABAD 500001	20 10 83
E-52, Chitaranjan Marg, C-Scheme, JAIPUR 302001	37 29 25
117/418 B, Sarvodaya Nagar, KANPUR 208005	21 68 76
Seth Bhawan, 2nd Floor, Behind Leela Cinema, Naval Kishore Road, LUCKNOW 226001	23 89 23
Patliputra Industrial Estate, PATNA 800013	26 23 05
T.C. No. 14/1421, University P. O. Palayam, THIRUVANANTHAPURAM 695034	6 21 17
Inspection Offices (With Sale Point) :	
Pushpanjali, 1st Floor, 205-A, West High Court Road, Shankar Nagar Square, NAGPUR 440010	52 51 71
Institution of Engineers (India) Building 1332 Shivaji Nagar, PUNE 411005	32 36 35

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*Sales Office is at 5 Chowringhee Approach, P.O. Princep Street, CALCUTTA 700072	27 10 85
†Sales Office is at Novelty Chambers, Grant Road, MUMBAI 400007	309 65 28
‡Sales Office is at 'F' Block, Unity Building, Narashimaraja Square, BANGALORE 560002	222 39 71

Reprography Unit, BIS, New Delhi, India